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PRELIMINARY ASSESSMENT OF TEMPERATURE INDUCED RADIOSONDE HUMIDI--ETC(U)

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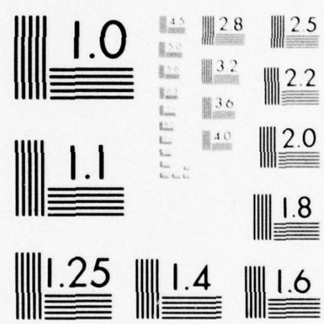
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PRELIMINARY ASSESSMENT OF TEMPERATURE INDUCED RADIOSONDE HUMIDITY ERRORS AND EFFECTS ON APPARENT LOW – LEVEL REFRACTIVE STRUCTURES

(Block Program WF 52-55-091 NEPRF).

By

(10) R.A. HELVEY
Geophysics Division

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PACIFIC MISSILE TEST CENTER
Point Mugu, California

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Standard radiosonde measurements and procedures are subject to significant temperature-induced humidity errors in the near surface layer. These errors, when experienced at coastal locations and applied to open ocean conditions may result in spurious surface-based ducts which have serious implications for the authenticity and application of world-wide refractive climatologies in naval planning and operations, and in the development and verification of prediction techniques. Efforts are underway

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PRELIMINARY ASSESSMENT OF TEMPERATURE-INDUCED RADIOSONDE HUMIDITY ERRORS AND EFFECTS ON APPARENT LOW-LEVEL REFRACTIVE STRUCTURES

(Block Program WF52-55-091 NEPRF)

By
R. A. HELVEY

SUMMARY

Standard radiosonde measurements and procedures are *subject to significant* temperature-induced humidity errors in the near surface layer. These errors, when experienced at coastal locations and applied to open ocean conditions may result in spurious surface-based ducts which have serious implications for the authenticity and application of world-wide refractive climatologies in naval planning and operations, and in the development and verification of prediction techniques. Efforts are underway at the Pacific Missile Test Center to determine the magnitude of this problem, and to recommend modified measurement procedures and correction factors that can be applied to existing data.

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PREFACE

Navy requirements exist for a prediction capability which will allow conversion of routine synoptic weather information to an assessment of meso-scale refractive structure and hence an inferred assessment of radar systems coverage. An initial subjective/objective effort based on worldwide radiosonde coverage and characteristic synoptic patterns resulted in the development of an initial Refractive Effects Guidebook (REG)[1]. While the prediction technique met with partial success, subsequent objective evaluations of REG performance indicated significant discrepancies in verification, particularly for surface-based ducts. These discrepancies can be explained by three factors: (1) A still incomplete understanding of synoptic-refractive relationships, (2) an overly detailed attempt to specify predicted profile types, and (3) deficiencies in radiosonde data when used for refractive purposes.

The first two problems are being addressed by PACMISTESTCEN in a continuing effort to develop improved prediction capabilities. The third problem is being simultaneously investigated and is the subject of this report.

A DAYTIME BIAS

In evaluating the performance of the REG[1], doubt has arisen concerning the authenticity of many of the surface-based refractive ducts derived from radiosonde data. Statistical summaries of surface-based duct occurrence compiled from these data indicate an inordinately large diurnal variation. The global distribution of differences in relative frequency of occurrence of surface-based ducts is depicted in figure 1, for "coastal" stations in a SYLVANIA[2] study covering the period May 1966 through April 1969. Locations where more ducts were noted at 00Z than at 12Z are indicated by squares; the reverse by "X"s; the size of the symbols is proportional to the differences in relative frequencies of occurrence observed between the two times, 00Z minus 12Z. It is immediately apparent that with very few exceptions, surface-based ducts were more frequent at 00Z on either side of the dateline between 90^{o}E and 90^{o}W, where 00Z occurs locally during daylight hours. The situation is reversed for the other side of the earth centered on the Greenwich meridian where 12Z is during daylight hours, although the pattern is not as clear-cut. The bias is greatest at low latitudes. Solar elevation angle is implicated as a direct or indirect cause, presumably by its effects on instrumentation or on actual conditions in the atmospheric boundary layer.

Diurnal variations in atmospheric properties over the open ocean should generally be quite small; day-night sea surface temperatures typically vary by no more than a few tenths of a degree C[3]. Unfortunately, however, with the exception of a few ocean station vessels, the soundings regularly available from oceanic areas are actually made over land from islands or near the coasts of continents. Temporarily putting aside the question of whether such soundings are representative of open ocean conditions, the observed diurnal variations found from the Sylvania statistics seem meteorologically implausible. The very limited extent of some of the island sites where the day-night variation is greatest suggests that changes in refractive layering due to diurnal variations in local winds are not the basic cause, especially since most of these surface-based ducts are very shallow. The establishment of daytime surface superadiabatic layers at land stations would be a common feature at nearly all

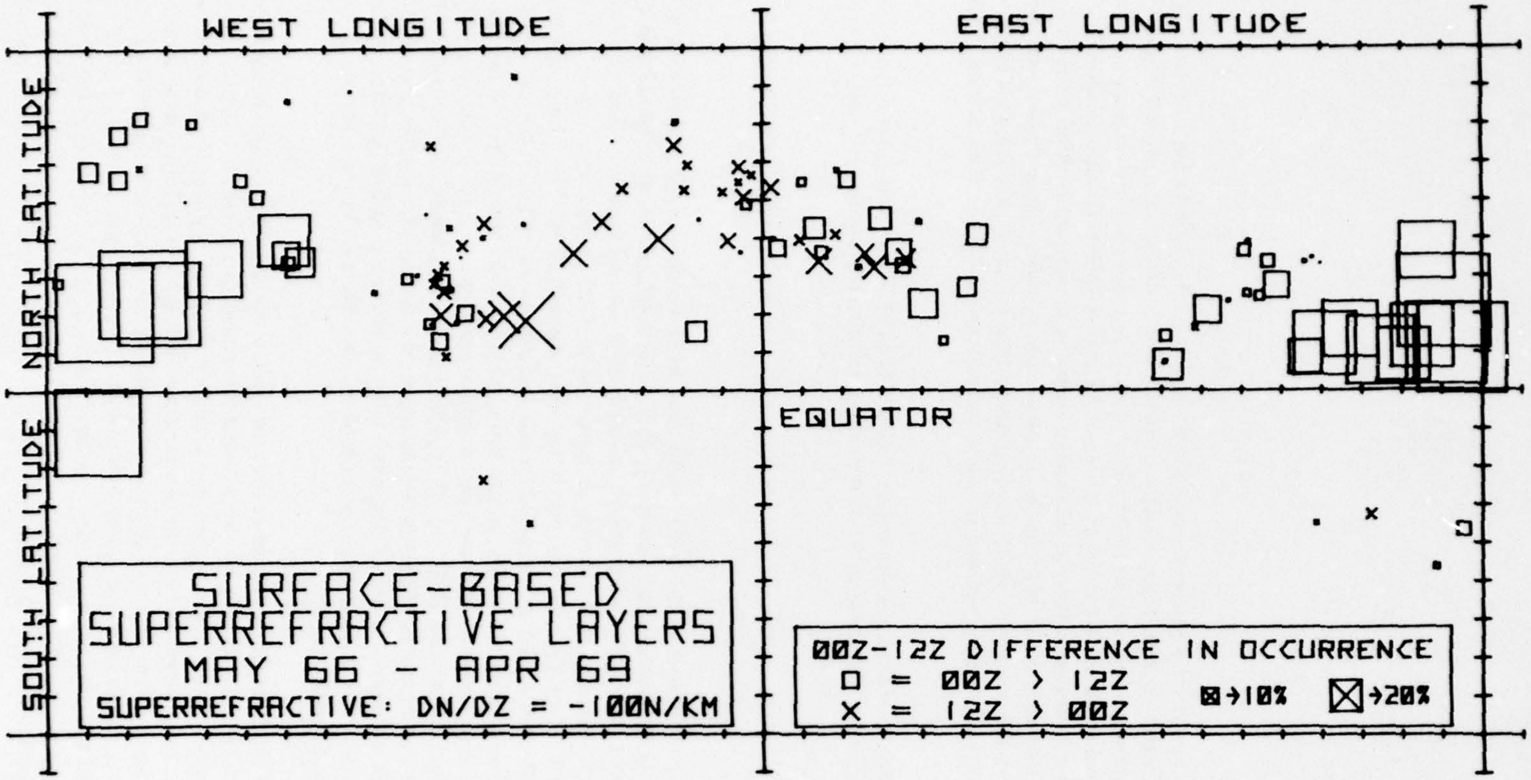


Figure 1. Global Distribution of Differences in Relative Frequency of Occurrence of Surface-Based Ducts.

sites, but except possibly in the case of wet soil[4], the associated strong vertical mixing should destroy any humidity stratifications which could cause superrefraction, and the rapid decrease of temperature with height would tend to cause subrefraction.

SOURCE OF THE BIAS

Radiosonde Humidity

The apparent marked surplus of these daytime surface-based ducts can be explained as a consequence of instrumental error. Most of the stations shown in figure 1 can be identified as sites where American radiosondes were employed. It has been known for some years that temperature-induced humidity errors have been responsible for a bias towards lower daytime relative humidities reported by U.S. radiosondes[5]. This is not merely the result of the inverse relationship between relative humidity and temperature, but represents a spurious reduction in daytime values of moisture in terms of dew point, mixing ratio, and other derived conservative moisture parameters. The cause is known to be warming of the hygristor (humidity element) due to solar radiation; the resultant increase in saturation vapor pressure of the air in contact with the hygristor leads to an erroneously low indication of relative humidity, which used in conjunction with the cooler temperatures from the sonde thermistor results in lowered calculated values for other moisture parameters. The microwave refractive index will also be too small. Above the surface layer this would have little effect on refractive gradient and duct calculations, since the bias would change slowly with altitude. But near the surface, significant refractive gradient errors could result. This follows from the fact that the surface point of soundings reduced according to standard procedures is obtained by psychrometer, as specified in FMH-3 (Federal Meteorological Handbook of Radiosonde Observations)[6]. The value for surface refractivity would therefore presumably be relatively accurate. Because the refractivity at the top of the surface layer is obtained from the radiosonde and hence liable to be erroneously small (dry) during daytime, a negative bias in the apparent change in refractivity upward through the surface layer will result. This in turn leads to a tendency for fictitious superrefractive gradients in this lowest layer of the sounding.

Attempts to assess and correct for spurious daytime dryness in U.S. radiosonde data from the Line Island[7], ATEX[7] and BOMEX[8] experiments led to introduction of a modified sonde[9] around 1971, designed to minimize hygristor heating by improving ventilation and shielding from sonde and solar heat sources. Although a considerable improvement in the accuracy of the upper-air humidities has been reported[10,11], a large dirunal variation in surface layer refractive conditions is still very much in evidence. Surface-based ducts continued in abundance during daytime hours in data obtained as late as 1974, as shown in table 1.

The apparent lack of any overall decrease in daytime surface duct bias is understandable if the following are taken into account: the special nature of the atmosphere in the surface boundary layer, the manner in which the data is obtained, and the effect of hygristor thermal lag on indicated humidities. For temperatures typical of the lower atmosphere over temperate and tropical regions the *humidity* response of the carbon hygristor type of humidity element in use for some years is quite good, with a lag coefficient less than one second. The *thermal* response of the carbon hygristor is much worse, however, with a lag coefficient near sea level around 15 seconds in the improved sonde introduced around 1971[12,13], and as much as a half-minute in the older sonde package[5,7] formerly used by the National Weather Service. The lithium chloride element in use some years ago was likewise subject to considerable thermal lag. At times when the sonde is ascending through a region with negative temperature lapse rate, the hygristor temperature will be too warm and hence indicated humidity and refractivity will be too low. For the current sonde and normal ascent rates the theoretical hygristor temperature excess due to lag (15-second time constant) can be estimated at about 0.5C for an ambient lapse rate of -2C/1000 feet, with a corresponding relative humidity deficit around 3%, and refractivity deficit of roughly 3 N-units. In the free atmosphere the refractivity gradient structure will be affected very little, except during passage through inversions (when the biases will be reversed with the hygristor tending to be cooler then the environment). But the situation is entirely different near the earth's surface. There, very strong negative temperature lapse rates in the daytime superadiabatic layer and internal boundary layer near coastlines during onshore flow will produce considerable reductions in apparent refractivity with height.

Table 1. Differences in Percent Occurrence of Surface-Based Ducts Reported at 00Z and 12Z, for Period May 1966-April 1969; and January/April/July/October 1974 (Frequency 00Z Minus Frequency 12Z)

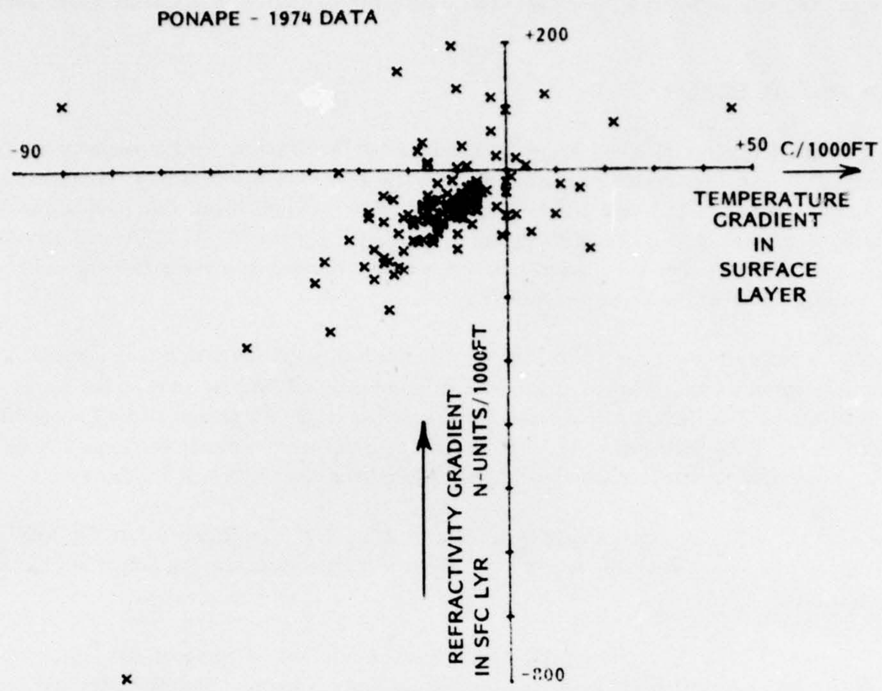
	Lat	Long	Station	%(00Z)-%(12Z) Differences for Periods: 1966-1969	1974
00Z = DAY	71N	157W	BARROW, ALASKA	-2	+1
12Z = NIGHT	52N	177W	ADAK, ALASKA	0	+2
	30N	140W	SHIP "N"	+16	+6
	28N	177W	MIDWAY ISLAND	+2	+15
	15N	121E	CLARK AFB, PHILLIPINE IS.	+8	+1
	9N	138E	YAP, CAROLINE IS.	+35	(+6)
	7N	158E	PONAPE, E. CAROLINE IS.	+27	+33
	14S	171W	PAGO PAGO, AMERICAN SAMOA	+51	+21
00Z = NIGHT	77N	69W	THULE AFB, GREENLAND	0	0
12Z = DAY	64N	23W	KEFLAVIC, ICELAND	-1	-12
	39N	27W	TERCEIRA, AZORES (LAJES FIELD)	-7	-12
	38N	70W	SHIP "H"	*	+2
	32N	65W	ST GEORGE, BERMUDA (USNAS)		-2
	32N	65W	ST GEORGE, BERMUDA (KINDLEY AFB)	-1	
	13N	60W	BARBADOS, W. INDIES (SEAWELL APT)	-24	-2
	9N	80W	BALBOA, CANAL ZONE (ALBROOK AFB)		+3
	9N	80W	BALBOA, CANAL ZONE (HOWARD AFB)	-3	
	7S	7W	DIEGO GARCIA (NAVCOMMSTA)	*	(-36)

* = NO DATA
( ) = LESS THAN 40 SOUNDINGS AT ONE OR BOTH TIMES
1966-1969 DATA FROM SYLVANIA REPORT (JULY 1972)
1974 DATA FROM PMTC STUDY

The influence of temperature lapse rate on refractivity is illustrated in figure 2a, where refractivity gradient versus temperature gradient is plotted for the first layer of soundings for Ponape, 1974 data. In general, the greater the decrease of temperature, the stronger the refractive layer was found to be. This temperature-induced problem is aggravated by still another problem—the increasing sensitivity of the computed refractive gradients to noise in the data as layer thickness becomes smaller. As apparent in figure 2b, even without noticeable correlation between layer thickness and refractive gradient, the larger scatter in the data for the thinner layers results in a greater number of extreme gradients—both superrefractive and subrefractive. Standard procedures dictate reduction of sonde data for mandatory pressure levels[6]. At most coastal and island stations the 1000mb level is as a rule within a few dozen feet of the surface, thus guaranteeing on reduced soundings a predominantly thin surface layer, with no direct physical basis for its reported depth.

Sonde Exposure Before Release

Exposure of the sonde prior to release can also contribute to a bias towards daytime ducts. Although redesign of the sonde has minimized radiative contributions to the hygristor temperature excess aloft[11], the hygristor remains vulnerable to heating by solar radiation during prerelease preparations because of inadequate ventilation. Cases are reported where a sonde has been allowed prior to release to lie outside on a hot surface such as the deck of a ship[5]. Even when reasonable care is exercised to avoid direct exposure to sunlight and relatively warm areas such as asphalt, substantial daytime warming of the sonde and hygristor can be expected before release under conditions of clear skies and light winds. Although according to FMH-3 the surface point would not be taken from the sonde in any event, a substantial period of time is required after release for recovery of the radiosonde from such overheating, due to the thermal lag of the hygristor and walls of the



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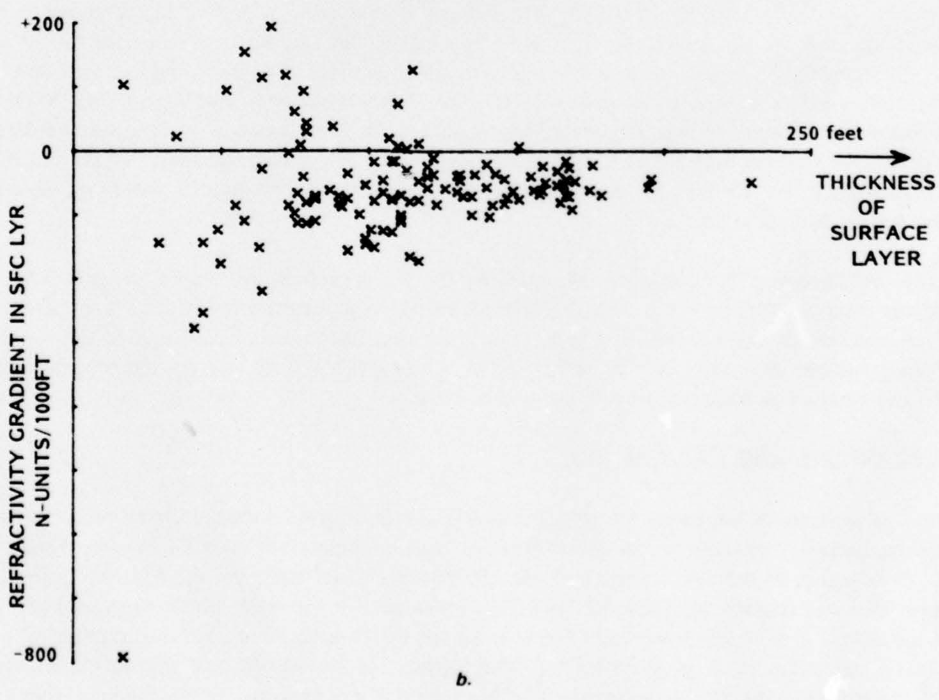

b.

Figure 2. Influence of Temperature Lapse Rate on Refractivity.

humidity duct. The contribution of this effect to the total humidity error is especially important when the first point from the sonde is selected within a few hundred feet of the surface, as when surface pressure is only slightly greater than 1000mb, or when a significant level is selected at the top of a shallow superadiabatic layer.

MAGNITUDE OF INITIAL ERROR

An estimate of the temperature of the hygristor element can be obtained for the moment of release if the radiosonde recorder chart and the surface psychrometer data are available. Regardless of temperature variations, and in the absense of wetting of the sonde and humidity element by precipitation, water vapor pressure should be essentially the same outside the sonde and in the air around the hygristor[12]. Thus the temperature of the latter is just that which together with the observed radiosonde initial ordinate value yields the same vapor pressure as that corresponding to the psychrometer data.

An example of a recorder chart for a sounding with substantial initial hygristor temperature excess is shown in figure 3. Humidity increases to the left, temperature to the right, and time upwards. The sonde was released at Point Mugu at 1024 PST, 30 July 1973, and had been modified to permit greater vertical resolution by increasing the switching rate between temperature and humidity. Skies were overcast with low stratus (which was beginning to clear, however), and surface winds were two knots from the southwest (onshore).

The sonde was one of the Weather Service types (J006) which had been modified at PACMISTESTCEN to reduce solar heating effects by covering the top of the hygristor duct with aluminum foil, and blackening the interior of the duct.

The surface humidity ordinate corresponding to the relative humidity reading of 78% obtained from electric psychrometer is shown as a circled point, far to the left and at a much higher humidity than that corresponding to the initial location of the sonde humidity trace. The latter indicated a relative humidity of 56%, using the psychrometer temperature of 18.8°C. The discrepancy between these two humidities corresponds to a hygristor temperature excess in this case of about 5.5°C. The sonde data indicate the top of a superadiabatic layer at 214 feet above the surface. (This level is indicated in figure 3 by the long horizontal dashed line at about 1/4 minute into the sounding.) Use of the actual humidity contact value for this level together with the surface psychrometer data yields a surface-based superrefractive layer with refractivity gradient of -119 N-units/1000 feet. If the humidity ordinate for the top of the superadiabatic layer is obtained by interpolation between the surface psychrometer readings and higher sonde points, however, a refractivity gradient of only -35 N-units per 1000 feet is calculated. In this example use of the actual contact value for humidity would clearly have resulted in a spurious surface-base duct.

Hygristor initial temperature excesses calculated by the above method are shown in figure 4 for Point Mugu soundings from September 1969, in which AMQ-9 military sondes were employed. This period was well before the introduction of extra radiation shielding. These values have been plotted against time of day, and clearly are separated into nighttime and daytime regimes. During the day the average temperature excess was around 4°C, and reached as high as 7 to 8°C on several occasions.

BIAS DUE TO INITIAL AND LAG ERRORS

In order to estimate actual humidity and refractivity distribution with altitude from radiosondes subject to initial and lag temperature-induced humidity errors, hygristor temperature must be known. First of all, it is required for reduction of the raw sonde hygristor data because of its effect on the relationship between hygristor resistance and relative humidity, but this effect is minor for the temperature range of concern here. Hygristor temperature is of much more importance, however, in correcting the apparent relative humidity for the difference in saturation vapor pressure between that in the free atmosphere and that in the air in immediate contact with the hygristor, when the temperature of the latter differs from the free air temperature as measured by the thermistor outside the sonde. Hygristor temperature can be measured directly by a thermistor placed on

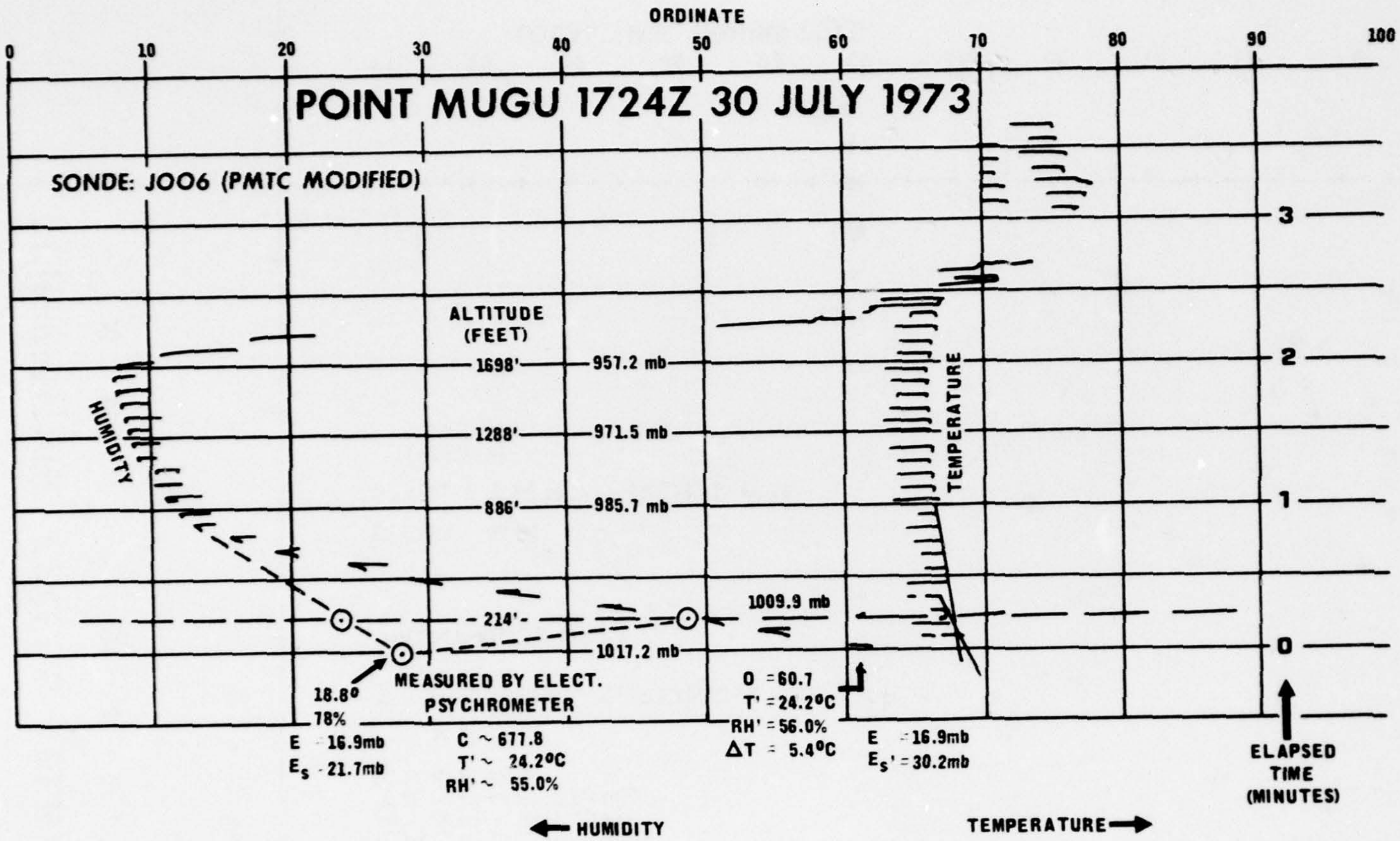

Figure 3. Example of a Recorder Chart for a Sounding With Substantial Initial Hygristor Temperature Excess.

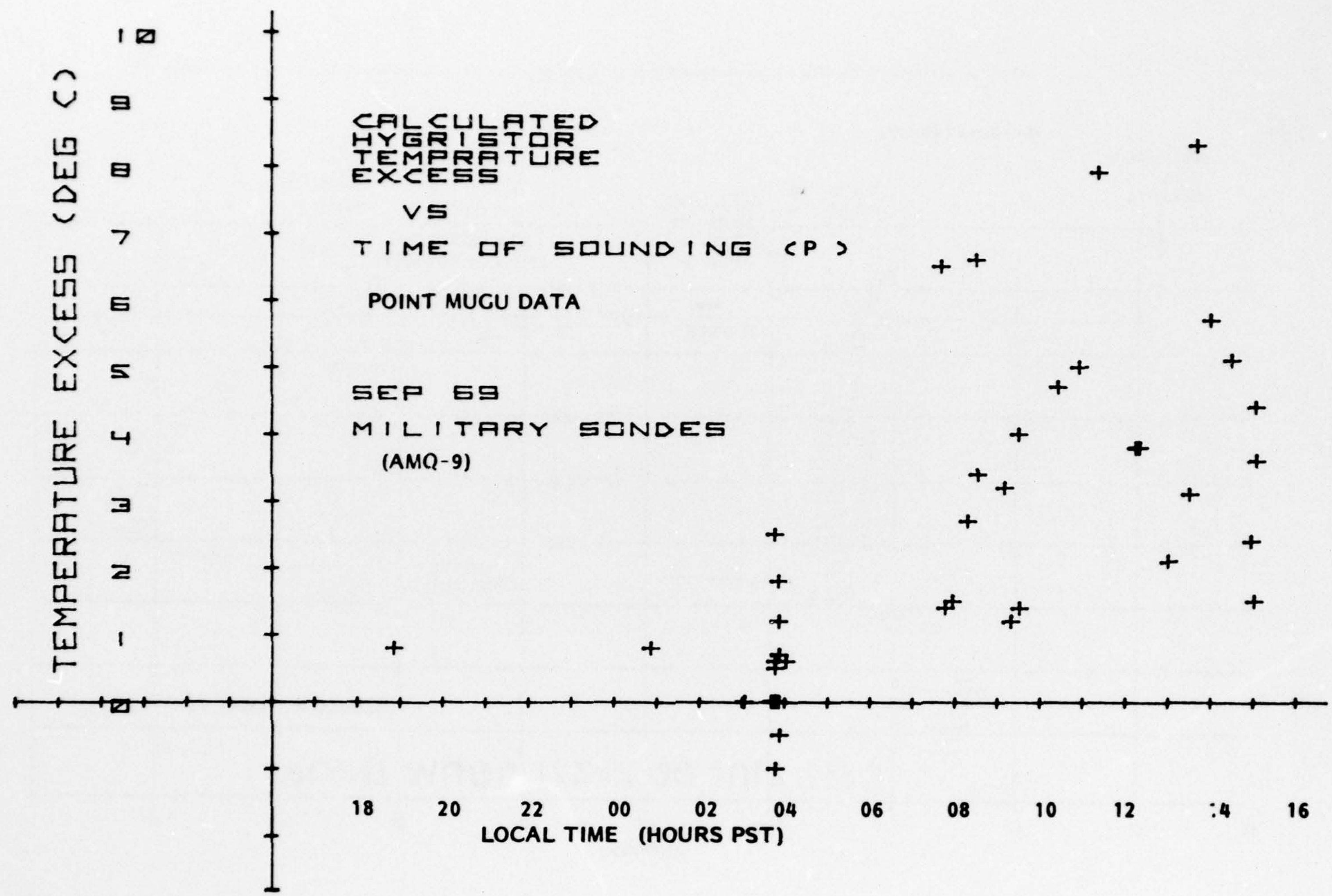

Figure 4. Calculated Hygristor Temperature Excess Versus Time of Sounding

the hygristor, but this requires provision for transmitting the additional temperature to the surface. Another approach involves calculating theoretical hygristor temperature response to measured free air temperatures, considering hygristor temperature error at the moment of release, and the effective hygristor thermal time constant (due to the combined thermal lag characteristics of the hygristor element and the surrounding duct, corresponding to a ventilation rate appropriate for the type sonde used and ascent rate experienced). Although heating of the hygristor due to solar radiation is the source of its initial temperature bias, this is much diminished aloft (in the improved sondes about +0.6°C near sea level) because of the increase in ventilation after release; therefore, in the discussion which follows, the contribution of radiation to the total error *aloft* has not been included.

Results of an application of the approach of calculating hygristor temperature are depicted in figure 5 using data from a pair of improved J005 Weather Service radiosondes released simultaneously at PACMISTESTCEN at 1705Z (0905PST) 4 May 1977; at time of release sky conditions were 3/10 cumulus, with onshore winds of 6 knots. The sondes were altered at PACMISTESTCEN to permit finer vertical resolution. Although the sonde packages were identical, they were each handled in a different manner prior to release. An accurate estimate of free air temperatures was needed for computing hygristor temperatures. To minimize effects of radiation on temperatures indicated by the thermistor at the moment of release and through the lower part of the sounding, one sonde was force-ventilated in a thermoscreen for about five minutes just before release. Temperature data from this sonde is shown as profile 1 in the upper left section of figure 5. This temperature profile was used to calculate a number of hypothetical examples of possible hygristor temperature variation with altitude, assuming various hygristor temperatures at the moment of release (expressed as "initial error" between hygristor and measured free air temperature), a hygristor thermal lag of 15 seconds, and ascent at the observed rate (858 ft/min) through the temperature environment indicated by profile 1. This value for thermal lag applies to the carbon hygristor in the J005 improved sonde package, as mentioned earlier; computed profiles 2, 3, and 4 differ solely as a result of different assumed initial hygristor temperature biases. In any event the effect of thermal lag in this situation with negative temperature lapse rates as shown by profile 1 would cause hygristor temperatures warmer than the free air, with consequences which are discussed below.

The other radiosonde was used to obtain raw hygristor data under conditions which would enhance hygristor vulnerability to overheating, and which are suspected to occur at times with routine soundings. This sonde was allowed to sit in the sun for the same five minute period of time prior to release, on top of a wooden box about one and one-half feet above an asphalt pavement. A substantial bias of hygristor temperature above that in the free atmosphere was observed to develop by the time of release which may be characteristic of routine soundings where precautions against pre-flight heating may not be taken; as inferred from the radiosonde recorder chart by the method outlined previously it amounted to about +4°C. This is the assumed initial error which resulted in generation of temperature profile 3; consequently that profile presumably comes closest to representing actual hygristor temperature behavior with altitude.

The sensitivity of some humidity-related parameters to hygristor temperature errors is demonstrated in the other boxed sections of figure 5, by profiles of relative humidity, mixing ratio, and refractivity, numbered in accordance with the particular hygristor temperature profile assumed. The raw hygristor data was first reduced using each of the temperature profiles in turn to obtain four sets of apparent relative humidities. In the case of profiles 2, 3, and 4 these humidities were then tentatively corrected for differences between the assumed hygristor temperatures represented by the correspondingly numbered temperature profiles, and the free air temperatures represented by temperature profile 1. Although the temperature and humidity information came from two separate sondes, it is believed that they sampled essentially the same volume of air due to their simultaneous release in close proximity. Profiles of mixing ratio and refractivity were computed from these corrected relative humidities and free air temperatures. In the case of profile 1 for the humidity parameters, no corrections were applicable, the hygristor temperature being assumed identical to the free air temperature. Of the relative humidity, mixing ratio, and refractivity profiles shown, profile 3 is probably most representative of actual atmospheric conditions for this sounding, as it was determined by corrections based on the most appropriate initial hygristor temperature as pointed out previously. On the other hand, except for the surface point (and the more detailed resolution of these soundings), profile 1 for the humidity-related parameters illustrates the kind of results to be expected under standard reduction procedures, which in effect assume zero hygristor thermal lag and initial bias by ignoring the effect of these sources of error on the humidity data after release. Under such

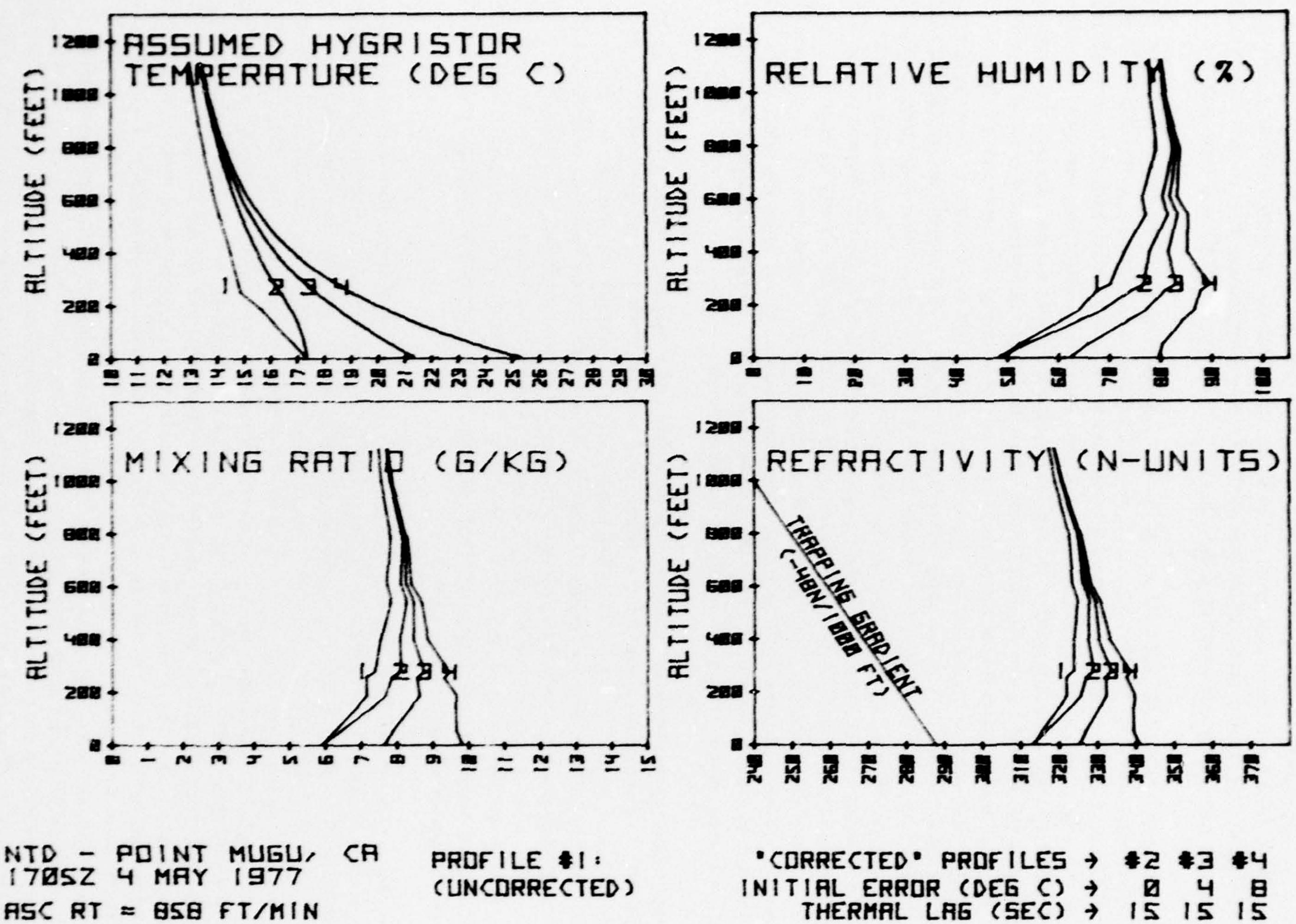

Figure 5. Effect of Initial and Lag Hygristor Temperature Errors.

procedures, the use of a psychrometer would have resulted in surface values close to the surface point of profile 1 for temperature, and profile 3 for the humidity-related parameters if the initial hygristor temperature bias was in fact about +4°C as has been inferred. While in terms of gradients there is little difference between profiles 1 and 3, the substitution of psychrometer data for the surface point together with the use of uncorrected radiosonde data aloft necessarily introduces a negative bias in the daytime vertical gradients of humidity and refractivity in the surface layer. The first significant (or mandatory) level above the surface defines the top of the surface layer, and in this sounding would probably be selected as the top of the superadiabatic layer evident at about 250 feet altitude in temperature profile 1. But in practice the apparent altitude of a significant level is to some extent fortuitous since the radiosonde does not transmit each parameter continuously; also, resolution is ordinarily somewhat poorer than in our special example here. While conditions in the surface layer in this case actually appear to have been subrefractive as indicated by refractivity profile 3, selection of the top of the surface layer at any altitude lower than about 200 feet and reduction under standard procedures would have resulted in a fictitious surface-based trapping layer.

TRENDS IN THE BIAS AT PACMISTESTCEN

Major changes in statistics of humidity and refractive gradients over the years have been noted in Point Mugu radiosonde data which support the preceding indications of contamination by temperature-induced humidity errors. Alterations in radiosonde instrumentation and data reduction procedures at Point Mugu from 1967 through 1976 are noted in figure 6, along with a plot of water vapor pressure variation with altitude through the first layer of selected soundings from that period, versus date. In order to provide a more homogeneous sample, the soundings represented were cases where the temperature decreased between 3 to 4°C from the surface to the top of the surface layer, and for which the top of that layer was between 100 to 400 feet above the surface.

A substantial decline in magnitude of the reported vapor pressure differences over the years is obvious, with the greatest change occurring between about 1971 and 1975, probably reflecting adoption of two major changes: modification of sondes starting July 1971 to minimize radiational heating, and utilization of a fan-ventilated thermoscreen for prerelease conditioning of the sondes starting in November 1974. Changes in refractive gradient statistics for the surface layer are also evident, as shown in figure 7. A remarkable decline in the reported frequency of occurrence of the more extreme refractive gradients took place over this period. In 1968, almost 40% of all soundings indicated surface-based trapping, dropping to less than 10% in 1975 and 1976. The jump from 1967 to 1968 is believed due to an increase in emphasis at that time in reporting smaller features in the sounding, and in a switching modification to increase humidity measurements.

OTHER CONSIDERATIONS IN ASSESSING OCEANIC REFRACTIVE STRUCTURE

A number of other considerations are involved in assessment of the authenticity and behavior of low-level oceanic refractive structure based on radiosonde data. Advective and subsidence processes will bring about strong surface-based refractive gradients of substantial depth in certain regions and weather regimes. But structures due to local land/sea effects which appear in island and coastal radiosonde data and which may be completely real, nevertheless may not be representative of open ocean conditions. Although soundings from ships on the open ocean should be free of such influences, another source of misinformation may arise in the presence of an evaporative duct. This type of duct is characterized by a fairly shallow surface-based superrefractive region due to the frequently strong, evaporation-caused decrease in humidity with altitude in the atmosphere immediately above the ocean surface. A sufficiently intense evaporative duct could be mistaken for a deeper surface-based duct because of the inability of a radiosonde to resolve the limited vertical extent of the former, with possibly serious effects on assessment of propagation conditions.

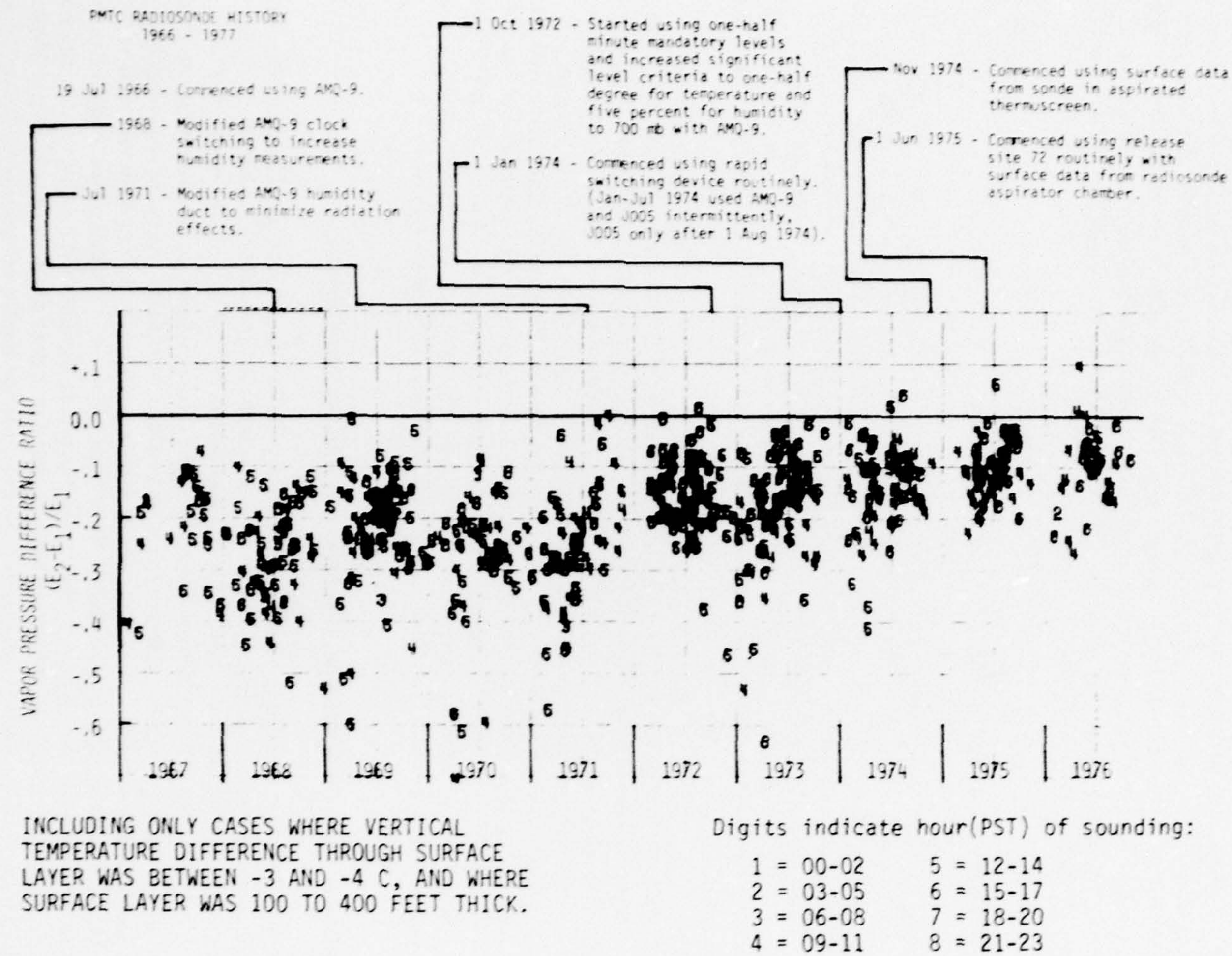

Figure 6. PMTC Radiosonde History and Vertical Change in Vapor Pressure Through the Surface Layer, 1966–1977.

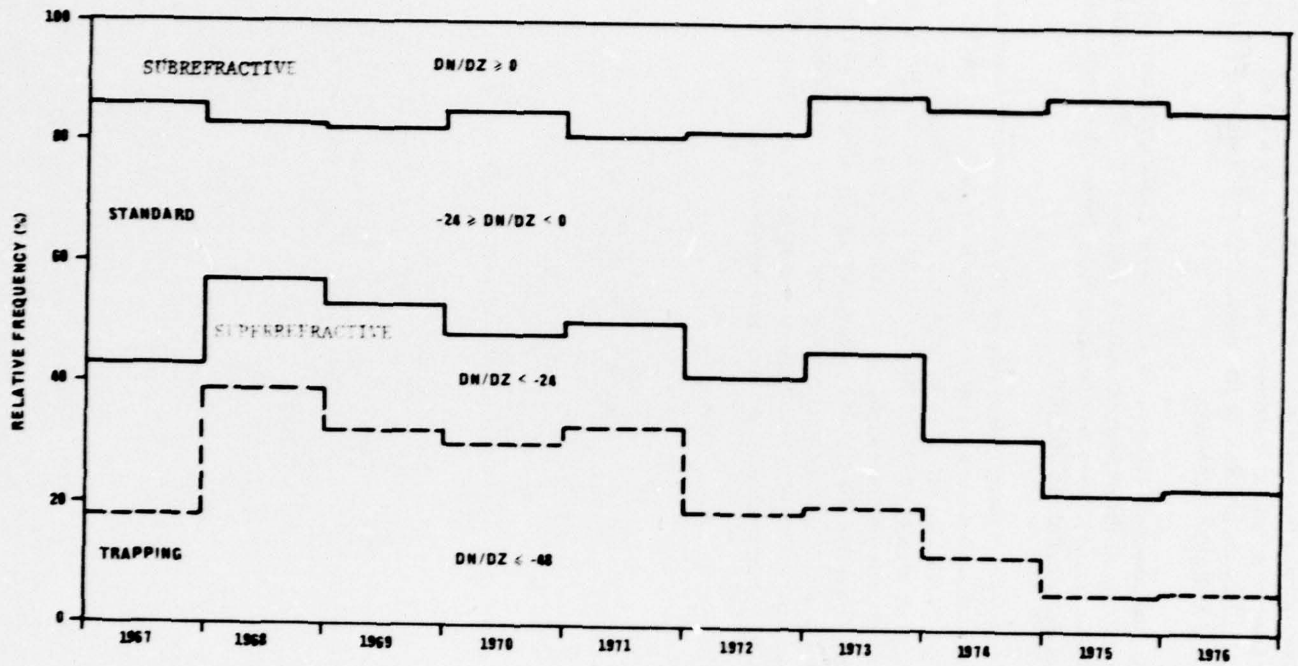

Figure 7. Relative Frequencies of Occurrence of Specified Refractive Gradients by Year, Surface Layer. Point Mugu Soundings.

CONCLUSIONS

On the basis of the large disparity in day/night surface-based duct occurrences calculated from radiosonde data reported at many stations, and the major decline in apparent duct occurrences accompanying improvements in instrumentation and procedures at Point Mugu, it is concluded that these ducts are apparently much less prevalent over the oceans than has been formerly indicated.

This is due to a combination of reduction and handling procedures, and temperature-induced humidity errors in U.S. and other radiosondes susceptible to radiational heating and thermal lag effects on humidity measurements. The problem has serious implications for the authenticity and application of refractive climatologies in naval planning and prediction techniques.

Although it seems unlikely that soundings taken in the past can be satisfactorily corrected on an individual basis due to difficulty in reconstructing all the relevant procedural, instrumental, and meteorological factors in effect at the time, the climatological contamination may be substantially reduced by application of results of comparative studies which are planned at PACMISTESTCEN.

Such studies will involve comparing standard radiosonde soundings with near-simultaneous soundings employing modified sondes or procedures such as are used operationally or planned at PACMISTESTCEN. The modifications include the use of ventilated shelters prior to balloon release to minimize errors due to lag and radiation. Comparative soundings are planned for Point Mugu, California; San Nicolas Island, off the California coast; Barking Sands, Hawaii and possibly other locations. It is hoped that from these studies, correction factors will be developed which will improve the climatological data presently available on low-level atmospheric refractive structure over the oceans, and lead to a firmer basis on which to develop techniques of predicting refractive structure from air mass and weather considerations. In addition, it is anticipated that procedures will be recommended which will result in improved accuracy for future measurements.

REFERENCES

1. Rosenthal, J. *Refractive Effects Guidebook (REG),* (published by NEPRF in April 1976, promulgated as Third Fleet TACMEMO 280-1-76 in December 1976, cancelled in July 1978 due to ongoing effort on proposed revision).

2. Ortenburger, L.N. *Radiosonde Data Analysis (May 1966-April 1969), Final Report.* GTE Sylvania, Electronic Systems Group, Western Division, Mt. View, California 94040, Contract: DAAB03-72-C-0027, 1 July 1973.

3. Sverdrup, H.V., M.W. Johnson, and R.H. Fleming. *The Oceans:* their physics, chemistry, and general biology. Englewood Cliffs, N.J., Prentice-Hall, 1942. (pp. 133-134)

4. Kerr, D.E. *Propagation of Short Radio Waves,* MIT (or Massachussetts Institute of Technology) Radiation Laboratory Series, no. 13, New York, McGraw-Hill Book Co., 1951. (p. 255)

5. Tewles, S. "A Spurious Diurnal Variation in Radiosonde Humidity Records", Bull. Amer. Meteor. Soc., V. 51, No. 9, September 1970. (pp 836-840)

6. *Radiosonde Observations.* Federal Meteorological Handbook No. 3 (FMH-3), U.S. Dept. of Commerce.

7. Ostapoff, F., W.W. Shinners, and E. Augstein. *Some Tests on the Radiosonde Humidity Error,* Atlantic Oceanographic & Meteorological Labs, Miami, Fla., ERL 194, December 1970.

8. Holland, J.Z. "Preliminary Report on the BOMEX Sea-Air Interaction Program", Bull. Amer. Meteor. Soc., V. 51, No. 9, September 1970. (pp. 815-816)

9. Brousaides, F.J. and J.F. Morrissey. "Improved Humidity Measurements with a Redesigned Radiosonde Humidity Duct", Bull. Amer. Meteor. Soc., V. 52, No. 9, September 1971. (pp. 870-875)

10. Shinners, W.W., G.E. Putland, and P.B. Conners. *Tests of Modified Radiosonde Hygristor Duct.* Atlantic Oceanographic & Meteorological Labs, Miami, Fla., NOAA-TM-ERL-AOML-15, December 1971.

11. Reihl, H., and A.K. Belts. *Humidity Observation with the 1972 U.S. Radiosonde Instrument.* Bull. Amer. Meteor. Soc., V. 53, No. 9, September 1972. (pp. 887-888)

12. Brousaides, F.J., *An Assessment of the Carbon Humidity Element in Radiosonde Systems.* Air Force Cambridge Research Labs, L.G. Hanscom AFB, Cambridge, MA, AFCRL-TR-73-0423, Instrumentation Papers, No. 197, 18 July 1973.

13. Brousaides, F.J. and J.F. Morrissey. *Residual Temperature-Induced Humidity Errors in the National Weather Service Radiosonde, Part I.* Air Force Cambridge Research Laboratories, L.G. Hanscom AFB, Cambridge, MA., AFCRL-TR-73-0214, 5 April 1973.

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